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THE EFFECTS OF NANO ADDITIVES ON PERFORMANCE AND EMISSION CHARACTERISTICS OF A VCR DIESEL ENGINE FUELLED WITH DIESEL-WATER EMULSION

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ABSTRACT

The present study investigates the performance and emission characteristics of single cylinder VCR diesel engine fuelled with nano additive blended diesel emulsion and the results are compared with neat diesel. The nano additives used for present investigation is AL_2 O_3 and CeO_2 nanoparticles. The base fuels taken for the experimental work is diesel, water and surfactants (span 80 and Tween 80). The test fuels were prepared by using an ultrasonicator with emulsion technique. The nano additives added for the test fuel is in the ratio of 50 ppm (25ppm AL_2O and 25ppm CeO_2) and 100 ppm (50ppm AL_2 O_3 and 50 ppm CeO_2). The entire investigation is conducted under constant speed and different load conditions. A substantial improvement in performance and a reduction in the exhaust emissions for the nano additive blended fuels compared to neat diesel were observed from the experimental results. For D88S2W10CA100 blend, optimum performance (BTH and BSFC) and emission (CO, NO_x , UBHC and CO_2) improvement were achieved as compared to other test fuels.

***KEYWORDS:** Nano Additives, Diesel-Emulsion, Performance & Emission*

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Original Article

NOMENCLATURE

Ceo2	**:** Cerium Oxide
Al2o3	**:** Alumina Oxide
Bth	**:** Brake Thermal Efficiency
Bsfc	**:** Brake Specific Fuel Consumption
Nox	**:** Nitrogen Oxides
Co	**:** Carbon Monoxide
Ubhc	**:** Unburnt Hydro Carbon
Co2	**:** Carbon Dioxide
D88s2w10	**:** 88% Diesel, 2% Surfactant And 10% Water
D88s2w10cz50	**:** 88% Diesel, 2% Surfactant And 10% Water, 50ppm (25ppm Ceo2 And 25ppm Al2o3)
D88s2w10cz100	**:** 88% Diesel, 2% Surfactant And 10% Water, 100ppm (50ppm Ceo2 And 50ppm Al2o3)

1. INTRODUCTION

The diesel engine is one of the main sources of air pollutant due to its combustion products. There is a significant focus going on for reducing exhaust emissions and better combustion characteristics of the diesel engine. Studies from the existing works revealed that there were two effective methods used for reducing the exhaust emissions released from the diesel engine [1]. The first method is using exhaust gas after-treatment techniques and the second method is using fuel additives [2–4]. The first method reduces the exhaust emission but unaffected the improvement in the performance of a diesel engine whereas the later one decreases the exhaust emission by simultaneously improving the performance of a diesel engine [5–7]. Nowadays there is extensive research focused on the development of water diesel emulsion as an alternative fuel due to their enormous advantages of adding water to diesel fuel [8]. By adding water into diesel, it reduces NO_x emissions because of lower combustion temperature which is due to the high latent heat of vaporisation of water, and also increases the brake thermal efficiency due to the increased ignition delay by addition of the lower amount of water to diesel [9]. The addition of water to diesel causes improved atomization and better mixing of air and fuel, as it enhances the combustion and lowers the formation of particulate matter (PM) [10]. It was also observed that by the addition of the higher amount of water to diesel causes a further increment in ignition delay and it lowers the brake thermal efficiency, as water carries no energy that increases the specific fuel consumption per unit power output [11–13]. These things are controlled by the addition of additives to water-diesel emulsion[14]. Use of nano-additivesis a new technology that improves the ignition delay period, calorific value and emission characteristics of the diesel engine[15]. An inclusion of nanoparticles, especially nano metal oxides acts as a catalyst in the combustion process which helps in enhancing the combustion characteristics that improves the performance and emission characteristics of the engine[16]. Nanoparticles have high surface area to volume ratio that improves the contact between fuel and oxidizer, furthermore nanoparticles are high energy density additives that causes an increase in the calorific value of the fuel. However, the stability of diesel emulsion is difficult to maintain long period for this instance surfactants are used to improve the stability of diesel emulsion by reducing interfacial tension between the oil and water phases. The selection of appropriate surfactant is based on the hydrophilic-lipophilic balance (HLB) value. The HLB value is varied from 1 to 20 depending on the emulsion type.

Some recent studies have been conducted on diesel fuel modification with the addition of nano additives. Rakhi N. Mehta et al. examined the effect of nanoparticles addition to diesel fuel on the combustion characteristics. The outcomes showed shortened ignition delay, longer flame sustenance, fast oxidation and reduction in peak cylinder pressure compared to the diesel fuel [15]. Mina Mehregan et al. numerically investigated on combustion characteristics of ethanol and n-decane liquid fuels blended with nano aluminium. It has been observed that the reduction in flame temperature, droplet evaporation rate and improved radiation by adding nano aluminium compared to pure ethanol and n-decane [16]. J. Sadhik Basha et al. carried out an investigation on the effect of alumina nanoparticles blended with biodiesel water emulsion on the performance, combustion and emission characteristics of a diesel engine. It was observed that there is an improvement in evaporation rate of fuel blended with nanoparticles and the experiment was carried out by hot plateignition setup. It was also observed that reduced peak pressure, ignition delay, NO_x, soot emissions and increased brake thermal efficiency by adding nanoparticles to biodiesel water emulsion [17]. Harish Venu et al. used titanium, zirconium oxides nano particles and Diethyl ether as additives to biodiesel-ethanol blends and concluded that titanium oxides mixed biodiesel-ethanol blends shown better combustion, performance and emission characteristics compared to other blends [18]. Soner Gumus et al. used aluminum oxide and copper oxide nanoparticles to diesel fuels and results were reported that lower emissions of CO, HC and NO_x produces up to 11%, 13% and 6%, with the addition of Al_2O_3 and up to

5%, 8% and 2% while addition of CuO nanoparticles to diesel fuel. The BSFC reduction for CuO and Al_2O_3 nano additives is up to o.5 % and 1.2% [19]. A. Prabu employed combined Alumina (Al_2O_3) and Cerium oxide (CeO_2) nanoparticles of each 30 ppm blended with biodiesel on the performance, combustion and emission characteristics of a single cylinder direct injection (DI) diesel engine. The results revealed that 12% increase in brake thermal efficiency and 30%, 60%, 44% and 38% reduction in NO_x, CO, HC and smoke emissions [20]. The above literature is shown that nano additives were used successfully to improve the performance and emission characteristics of a diesel engine. Although, very few studies have been conducted on the effect of incorporation of two mixed nanoparticles as additives for diesel-water emulsion fuel. In view of this, an attempt has been made to study the effect of mixed nanoparticles as additives to diesel-water emulsion on the performance and emission characteristics of diesel engine and compared with neat diesel fuel.

2. MATERIALS AND METHODS

A stationary single cylinder water cooled variable compression ratio (VCR) diesel engine is used for this experimental investigation. The experimental setup and engine specifications are shown in Figure 1. and Table 1. The hydraulic dynamometer was used to apply load to the engine. The fuel tank is placed over the cantilever type load cell, which measures the fuel flow rate by measuring the loss of weight of fuel in the fuel tank. Air consumption is measured by using an orifice manometer. The proximity sensor has been used to measure the speed of the engine. A water-cooledPiezoelectric pressure sensor and rotary encoders are provided to measure the combustion chamber pressure and correlated crank angle. The exhaust gas temperature is measured with a K- type thermocouple, which is mounted on the exhaust pipe. The engine's exhaust emissions were measured using a Pantron multi-gas analyser made by Pantron Automation Pvt. Ltd. The gas analyser measures the CO, NO_x, HC and CO_2 emissions. The computerized engine analysis software (TECH-ED) has been used to collect the test parameters and analyses the performance parameters. The Al_2O_3 and CeO_2 nanoparticles are purchased by Nano research lab, India, and their average particle size is 30 – 50nm and 20-30nm. The nanoparticles dispersion is done by using an ulatrasonicator. The fuel blends are prepared by using the emulsion technique and the percentage of fuel contains is 88% of diesel, 10% of water and 2% of surfactant (span80 and Tween 80). The prepared blends were added by 50ppm (25ppm AL_2O_3 and 25ppm CeO_2) and 100ppm (50ppm AL_2O_3 and 50 ppm CeO_2) of nanoparticles. The properties of the test fuel blend shown in Table 2. The engine experiments were carried out under different loads at a constant speed of 1500rpm. The engine was fuelled with neat diesel, water-diesel emulsion and nanoparticle blended diesel water emulsion blend. The test results were taken under steady-state conditions by running the engine 30 min for each fuel. For each fuel blend, more than three test runs are conducted under steady conditions to check the reliability of the measurements and the test results obtained by the repeatability of the test run are found to be good.

Table 1: Specifications of Diesel Engine

Description	Specifications
Type	4 stroke single cylinder water cooled VCR Direct injection diesel engine
Bore × Stroke	80 × 110 mm
Connecting rod length	234 mm
Swept volume	552cc
Compression ratio	17:1
Rated power	up to 5 HP(3.7 KW)
Rated Speed	1500 rpm

Table 2: Properties of Test Fuel Blend

Properties	Diesel	D88S2W10	D88S2W10CA50	D88S2W10CA100
Density at 15^o C (kg/m3)	837.8	858.32	859.17	860.21
Kinematic Viscosity at 40^o C (cst)	2.65	4.92	5.06	5.11
Flash point ^{o}C	52	60	63	65
Calorific Value (kj/kg)	44893	42087	42430	42862

Figure 1: Experimental Test Setup

3. RESULTS AND DISCUSSIONS

The following section shows the results of the performance and emission characteristics of the diesel engine fuelled with different fuel blends. The variation of the performance parameters (BTH and BSFC) and the emission characteristics (NOx, CO, UBHC and CO_2) were plotted against the load.

3.1. Brake Thermal Efficiency (BTH)

The variation of BTE with respect to load for neat diesel, D88S2W10, D88S2W10CA50 and D88S2W10CA100 blends is shown in Figure 2. It was observed from the experimental results the BTH increases with increased load on the engine for all test blends. This is due to the increased cylinder temperature at higher loads. It can be seen from Figure 2 the addition of water to diesel fuel resulting in are duction in BTH and addition of nano additives improves the brake thermal efficiency with respect to the concentration level of nanoparticles. High catalytic activity, high surface-to-volume ratio of nanoparicles and combined effect of micro-explosion and secondary atomization are the possible reasons. The micro explosion is caused by the difference in latent heat of absorption of water and diesel. It has been observed that the maximum BTH is obtained for D88S2W10CA100 blend is 28.12% at full load and the percentage of increment compared to neat diesel is 7.49%.

3.2. Brake Specific Fuel Consumption (BSFC)

The variation of BSFC with respect to different loads for all test blends is shown in Figure 3. It was observed that the BSFC decreases with increasing the load on the engine for all text fuels, this might be due to improved combustion at higher loads. Adding water to diesel fuel results in an increase in BSFC due to lower calorific value of diesel water mixture. The results showed that adding nano additives to test fuel blends leads to an improvement in BSFC. This could be attributed due to the enhanced surface area to volume ratio, improved fuel air mixing and shortened ignition delay. It was observed that for D88S2W10CA100 blend, the lowest BSFC is 0.313 kg/kw-hr at full load and the percentage of reduction is 2.19% compared with neat diesel.

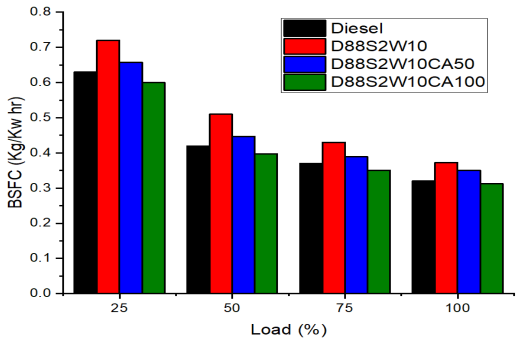

Figure 2: Variation of BTE with Respect to Load

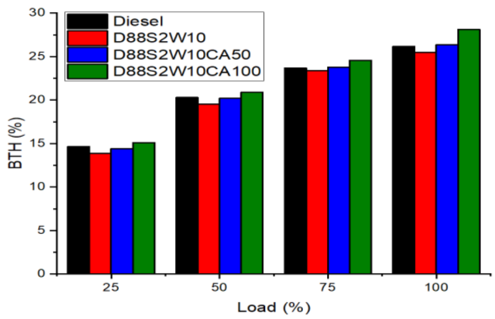

Figure 3: Variation of BSFC with Respect to Load

3.3. Nitrogen Oxides (NO_x) Emissions

NO_x emission Variation with load for all test blends is presented in Figure 4. NO_x emissions are increases as the load on the engine increases because of the increased combustion temperature at higher loads. For all fuel blends the lowest NO_x is318, 291, 297 and 274 ppm at 25% load on the engine for neat diesel, D88S2W10, D88S2W10CA50 and D88S2W10CA100. It was observed that there is a significant reduction in NO_x emissions due to the addition of water and nano particles. It was also observed that at full load the lowest NO_x emission is obtained for D88S2W10CA100 blend is 550 ppm and the percentage of reduction in NO_x emission is 30.03% when compared to neat diesel fuel.

3.4. Carbon Monoxide (CO) Emission

Figure 5 shows the variation of CO emission with load for all test fuels. By increasing the load the magnitude of CO emission is increased. Compared to neat diesel and D88S2W10 blend the addition of nano additives reduces the CO emissions in all loads. This is attributed due to the improved air fuel mixing causes rapid evaporation, secondary atomization and the catalytic activity of nanoparticle in the combustion chamber causes enhanced burning rate. The lowest CO emission is found for D88S2W10CA100 blend at 25% of load and the maximum percentage of reduction is 19.96% obtained at full load compared with neat diesel fuel.

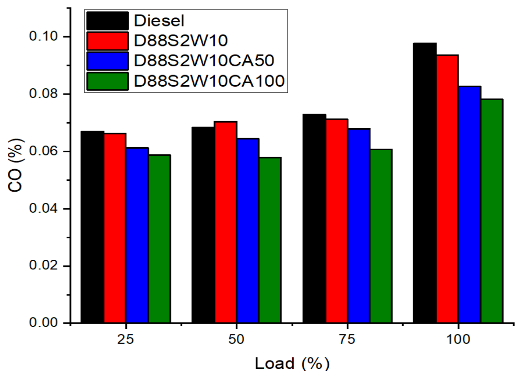

Figure 4: Variation of NO_x with Respect to Load

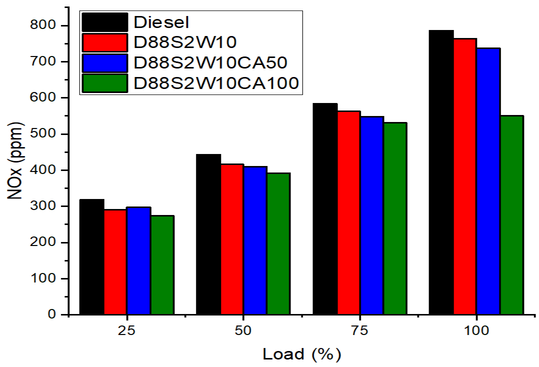

Figure 5: Variation of CO with Respect to Load

3.5. Unburned Hydrocarbon (UBHC) Emissions

Figure 6 shows the variation of UBHC emissions for all test fuels with respect to load. It was observed that the magnitude of UBHC emissions were increasing with increased load. The reason for this is that air fuel mixture supplied to the engine at higher loads is rich mixture which causes incomplete combustion due to the lack of oxygen in the combustion chamber. For all test blends, the lowest UBHC was obtained at 25% load. It was also observed that at full load the lowest UBHC is obtained for D88S2W10CA100 and the percentage of reduction is 20.93 when compared to neat diesel fuel.

3.6. Carbon Dioxide (CO_2) Emissions

Figure 7 shows the variation of CO2 emissions for all fuel blends with respect to the load. It was seen that the percentage of CO2 increased with increasing load for all fuel blend, it clearly indicates that the efficiency of combustion is improved at higher loads. It has been observed that with the addition of water to diesel fuel CO2 emission is decreasing and increases with the addition of nano additives. Nano particles have high surface to volume ratio which increases the fuel and oxidizer contact so that it enhances the oxidation and causes complete combustion. The lower CO2 emissions were obtained at 25 % load for all test fuel blends. It was seen that at full load the CO2 emissions are 7.95, 7.86, 7.92 and 8.1 for neat diesel, D88S2W10, D88S2W10CA50 and D88S2W10CA100.

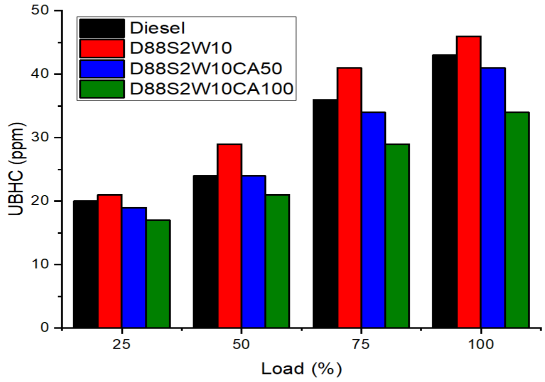

Figure 6: Variation of UBHC with Respect to Load

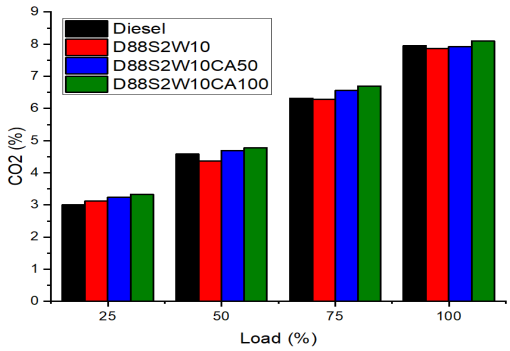

Figure 7: Variation of CO2 with Respect to Load

4. CONCLUSIONS

- Nano particles incorporated test fuel performance and emission characteristics were investigated and compared with neat diesel fuel. The following conclusions can be drawn on the basis of experimental results
- The addition of nanoparticles to diesel water emulsion significantly enhances the performance parameters of BTH and BSFC. The maximum BTH and minimum BSFC is 28.12% and 0.313 for D88S2W10CA100 blend at full load.
- The NO_x and CO emissions were decreased significantly by the addition of nano additives to diesel water emulsion blends compared to neat diesel. The lowest NO_x and CO emissions are 550ppm and 0.0782% obtained for D88S2W10CA100 blend.
- Significant improvement is found in UBHC emissions with the addition of nano additives. D88S2W10CA100 blend shows the minimum UBHC at all cases and the minimum UBHC at full load is 34ppm. Furthermore, it is also observed that CO_2 emissions were increased by addition of nano addtive to diesel water emulsion blend.
- As a whole, the addition of nano additives improves the performance and emission characteristics of test fuel compared with neat diesel.

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